IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants:	T.L. Ritzdorf et al.	Attorney Docket No.:	SEMT116123
Application No.:	Filed Concurrently Herewith	Group Art Unit:	--
Filed:	Concurrently Herewith	Examiner:	--
Title:	METHOD AND APPARATUS FOR LOW-TEMPERATURE ANNEALING OF METALLIZATION MICROSTRUCTURES IN THE PRODUCTION OF A MICROELECTRONIC DEVICE		

PRELIMINARY AMENDMENT

Seattle, Washington 98101

June 20, 2001

TO THE COMMISSIONER FOR PATENTS:

Prior to examination, please amend the above-identified application as follows:

In the Specification:

Please amend the specification as follows:

On page 1, line 6, beneath the heading "CROSS-REFERENCE TO RELATED APPLICATIONS", please delete the words "Not Applicable" and insert the following new paragraph:

> This application is a continuation of U.S. Application Serial No. 09/387,577 filed August 31, 1999, which is a continuation of International Application Serial No. PCT/US99/02504 designating the United States filed February 4, 1999, which is a continuation-in-part of U.S. Application Serial No. 09/018,783 filed February 4, 1998 and claims the benefit of U.S. Provisional Application Serial No. 60/087,432 filed June 6, 1998, priority from the filing dates of which are hereby claimed under 35 USC Sections 120 and 119(e), and the disclosures of which are hereby incorporated in their entirety.

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In the Claims:

Please cancel Claims 1-67.

Please add new Claims 68-106 as follows:

68. (New) A process for electrochemical deposition of metal onto a surface of a microelectronic workpiece including at least one low-K dielectric layer, comprising:

exposing a surface of the microelectronic workpiece to a plating solution including a principal metal species to be deposited;

applying plating power between the surface of the workpiece and an electrode disposed in contact with the plating solution to electrolytically deposit metal onto the surface, wherein plating power is applied

at a first current density for a first period of time to deposit a first layer of the metal onto the surface of the workpiece, and subsequently

at a second current density for a second period of time to deposit a second layer of the metal onto the first layer of metal, wherein the second current density is substantially greater than the first current density and a majority of the metal deposited onto the surface of the workpiece is deposited during the second time period; and

subjecting the surface of the microelectronic workpiece to an elevated temperature annealing process at a predetermined temperature that is below a temperature at which the low-K dielectric layer would substantially degrade.

69. (New) The process of Claim 68, wherein the surface of the microelectronic workpiece defines a plurality of recessed microstructures, and the first current density and first period of time are selected to at least partially fill the recessed microstructures with the deposited metal.

70. (New) The process of Claim 68, wherein metal deposited during the first time

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period has a grain size that is sufficiently small to fill the recessed microstructures and at least some of the recessed microstructures have a width of less than or equal to 0.3 micron.

71. (New) The process of Claim 68, wherein the metal is annealed at a temperature of at or below about 250° C.

72. (New) The process of Claim 68, wherein the first current density is about 3.2 mA/cm^2.

73. (New) The process of Claim 68, wherein the second current density is about 20 mA/cm^2.

74. (New) The process of Claim 68, wherein a ratio of the second current density to the first current density is about 6:1.

75. (New) The process of Claim 68, wherein the first time period is about 30 seconds.

76. (New) The process of Claim 68, wherein the metal is annealed at a temperature of at or below about 250° C to 300° C.

77. (New) The process of Claim 68, wherein metal is deposited at a higher rate during the second time period than during the first time period.

78. (New) The process of Claim 68, further comprising depositing a seed layer onto the surface of the microelectronic workpiece prior to the first time period, the first layer of metal being deposited onto the seed layer.

79. (New) The process of Claim 68, wherein the principal metal species deposited comprises copper.

80. (New) A process for electrochemical deposition of copper onto a surface of a microelectronic workpiece, comprising:

exposing a surface of the microelectronic workpiece to a plating solution including copper as a principal metal species to be deposited;

applying plating power between the surface of the workpiece and an electrode disposed in contact with the plating solution to electrolytically deposit copper onto the surface, wherein plating power is applied

at a first current density for a first period of time to deposit a first layer of copper onto the surface of the workpiece, and subsequently

at a second current density for a second period of time to deposit a second layer of copper onto the first layer of copper, wherein the second current density is substantially greater than the first current density and a majority of copper deposited onto the surface of the workpiece is deposited during the second time period; and

subjecting the surface of the microelectronic workpiece to an elevated temperature annealing process at a predetermined temperature that is below about 300° C.

81. (New) The process of Claim 80, wherein the second current density is applied immediately after the first period of time.

82. (New) A process for electrochemical deposition of metal onto a surface of a microelectronic workpiece, the surface defining a plurality of recessed microstructures, the workpiece including at least one low-K dielectric layer, comprising:

exposing a surface of the microelectronic workpiece to a plating solution including a principal metal species to be deposited;

applying plating power between the surface of the workpiece and an electrode disposed in contact with the plating solution to electrolytically deposit metal onto the surface, wherein plating power is applied

at a first current density for a first period of time to deposit a first layer of the metal onto the surface of the workpiece to at least partially fill the recessed microstructures, and subsequently

at a second current density for a second period of time to deposit a second layer of the metal onto the first layer of metal, wherein the second current density is substantially greater than the first current density; and

subjecting the surface of the microelectronic workpiece to an elevated temperature annealing process at a predetermined temperature that is below a temperature at which the low-K dielectric layer would substantially degrade.

83. (New) The process of Claim 82, wherein the second current density is applied immediately after the first period of time has elapsed.

84. (New) A process for electrochemical deposition of metal onto a surface of a microelectronic workpiece, the workpiece including at least one low-K dielectric layer, comprising:

applying a metal seed layer onto a surface of the microelectronic workpiece;

exposing the surface of the microelectronic workpiece to a plating solution including a principal metal species to be deposited;

applying plating power between the surface of the workpiece and an anode disposed in contact with the plating solution to electrolytically deposit metal onto the surface, wherein plating power is applied

at a first current density for a first period of time to deposit a first layer of the metal onto the seed layer on the surface of the workpiece, and subsequently

at a second current density for a second period of time to deposit a second layer of the metal onto the first layer of metal, wherein the second current density is substantially greater than the first current density; and

subjecting the surface of the microelectronic workpiece to an elevated temperature annealing process at a predetermined temperature that is below a temperature at

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which the low-K dielectric layer would substantially degrade.

85. (New) A method of depositing a metal layer on a semiconductor wafer, the workpiece including at least one low-K dielectric layer, comprising:

depositing a seed layer on a surface of the wafer;

immersing the wafer in an electrolytic solution containing metal ions;

electrolytically depositing a first plated layer on the wafer by applying current at a first current density between the wafer and the solution;

after a first period of time during which the first plated layer has been formed, increasing the applied current to a second current density greater than the first current density to plate additional metal onto the first plated layer; and

subjecting the surface of the microelectronic workpiece to an elevated temperature annealing process at a predetermined temperature that is below a temperature at which the low-K dielectric layer would substantially degrade.

86. (New) An apparatus for use in electrochemical deposition of metal onto a surface of a microelectronic workpiece, the workpiece including at least one low-K dielectric layer, comprising:

an electrochemical deposition station comprising

a reactor that receives a surface of the microelectronic workpiece in a chamber in which the surface of the microelectronic workpiece is exposed to a plating solution including a principal metal species to be deposited,

an electrode disposed in contact with the plating solution, and

a source of plating power supplied between the electrode and the surface of the microelectronic workpiece to deposit metal from the plating solution onto the surface of the microelectronic workpiece, wherein the source of plating power is operated to supply power at a

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first current density for a first period of time to deposit a first layer of metal onto the surface of the workpiece, and then at a second current density for a second period of time to deposit a second layer of metal onto the first layer of metal, and wherein the second current density is substantially greater than the first current density and the majority of metal is deposited onto the surface of the workpiece during the second time period; and

an annealing station for subjecting the surface of the microelectronic workpiece to an elevated temperature annealing process at a predetermined temperature that is below a temperature at which the low-K dielectric layer would substantially degrade.

87. (New) The apparatus of Claim 86, wherein the annealing station comprises:

a heat generator proximate the workpiece to heat the workpiece during a heating cycle; and

a cooling system disposed proximate the workpiece to cool the workpiece.

88. (New) The apparatus of Claim 87, wherein the cooling system is superimposed relative to the heat generator.

89. (New) The apparatus of Claim 88, wherein the cooling system comprises a fluid flow system that directs a flow of cooling fluid relative to a side of the workpiece.

90. (New) The apparatus of Claim 88, wherein the cooling system comprises a fluid flow system that directs a flow of cooling fluid such that the cooling fluid directly contacts the workpiece.

91. (New) The apparatus of Claim 88, wherein the cooling system comprises a fluid flow system that directs a flow of cooling fluid through a heat sink configured to draw heat away from the workpiece.

92. (New) The apparatus of Claim 88, wherein the heat generator comprises a hot plate contacting a first side of the workpiece.

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93. (New) The apparatus of Claim 88, wherein:

the heat generator comprises a hot plate at least proximate to a first side of the workpiece; and

the cooling system comprises a heat sink at least proximate to a second side of the workpiece.

94. (New) The apparatus of Claim 88, further comprising a programmable control system operatively coupled to the heat generator and the cooling system to control the time and temperature of the heating and cooling cycles so that the workpiece is annealed at a temperature that is at or below 250 °C.

95. (New) The apparatus of Claim 88, further comprising a programmable control system operatively coupled to the heat generator and the cooling system to control the time and temperature of the heating and cooling cycles so that the workpiece is annealed at a temperature that is at or below about 250 °C to 300 °C.

96. (New) The apparatus of Claim 86, wherein the annealing station is configured to subject the workpiece to an annealing temperature that is at or below 250 °C.

97. (New) The apparatus of Claim 86, wherein the annealing station is configured to subject the workpiece to an annealing temperature that is at or below about 250 °C to 300 °C.

98. (New) The apparatus of Claim 86, further comprising an enclosure, wherein the electrochemical deposition station and the annealing station are disposed within the enclosure.

99. (New) The apparatus of Claim 98, further comprising an input/output station associated with the enclosure that receives workpieces.

100. (New) The apparatus of Claim 98, further comprising an intermediate staging door disposed within the enclosure between the electrochemical deposition station and the annealing station.

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101. (New) The apparatus of Claim 86, further comprising at least one wet-chemical processing station.

102. (New) The apparatus of Claim 86, further comprising a rinsing/drying station.

103. (New) The apparatus of Claim 86, further comprising a workpiece transfer station that transfers the workpiece between the electrochemical processing station and the annealing station.

104. (New) The apparatus of Claim 103, wherein the workpiece transfer system comprises at least one transfer robot that transfers workpieces between the electrochemical deposition station and the annealing station.

105. (New) The apparatus of Claim 86, wherein the at least one electrochemical deposition station electrolytically deposits copper onto the microelectronic workpiece.

106. (New) An apparatus for use in electrochemical deposition of metal onto a surface of a microelectronic workpiece, the workpiece including at least one low-K dielectric layer, comprising:

electrochemical deposition means for depositing metal onto the workpiece comprising

reactor means for receiving a surface of the microelectronic workpiece in a chamber in which the surface of the microelectronic workpiece is exposed to a plating solution including a principal metal species to be deposited,

an electrode disposed in contact with the plating solution, and

power supply means for supplying power between the electrode and the surface of the microelectronic workpiece to deposit metal from the plating solution onto the surface of the microelectronic workpiece, wherein the power supply means is operated to supply power at a first current density for a first period of time to deposit a first layer of metal onto the surface of the workpiece, and then at a second current density for a second period of time to deposit a

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second layer of metal onto the first layer of metal, and wherein the second current density is substantially greater than the first current density and the majority of metal is deposited onto the surface of the workpiece during the second time period; and

annealing means for subjecting the surface of the microelectronic workpiece to an elevated temperature annealing process at a predetermined temperature that is below a temperature at which the low-K dielectric layer would substantially degrade.

REMARKS

Please enter the above preliminary amendment prior to examination of the application.

Respectfully submitted,

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<u>VERSION WITH MARKINGS TO SHOW CHANGES MADE JUNE 20, 2001</u>

<u>In the Specification</u>:

At page 1, line 6, in the section entitled "CROSS-REFERENCE TO RELATED APPLICATIONS", a new paragraph has been substituted for the existing words "Not Applicable".

<u>In the Claims</u>:

Claims 1-67 have been canceled.

Claims 68-106 have been added.

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